FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

# TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
**112740-339**

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
10/019924

| INTERNATIONAL APPLICATION NO. | INTERNATIONAL FILING DATE | PRIORITY DATE CLAIMED |
|---|---|---|
| **PCT/DE00/01231** | **April 19, 2000** | **April 22, 1999** |

TITLE OF INVENTION
**METHOD FOR CORRECTING FREQUENCY ERRORS IN SUBSRIBER STATIONS**

APPLICANT(S) FOR DO/EO/US
**Gerhard Ritter**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☒ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

**Items 13 to 20 below concern document(s) or information included:**

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

**Formal Drawings (4 sheets)**
**Return Receipt Postcards**

531 Rec'd PCT/PTO 22 OCT 2001

| U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR) 10/019924 | INTERNATIONAL APPLICATION NO. PCT/DE00/01231 | ATTORNEY'S DOCKET NUMBER 112740-339 |
|---|---|---|

| 24. The following fees are submitted:. | CALCULATIONS | PTO USE ONLY |
|---|---|---|
| **BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5)) :** | | |
| ☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO . . . . . . . . . . . . **$1040.00** | | |
| ☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO . . . . . . . . **$890.00** | | |
| ☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO . . . . . . . . . . . . **$740.00** | | |
| ☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) . . . . . . . . . . . . **$710.00** | | |
| ☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) . . . . . . . . . . **$100.00** | | |
| **ENTER APPROPRIATE BASIC FEE AMOUNT =** | **$890.00** | |
| Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)). | **$0.00** | |

| CLAIMS | NUMBER FILED | NUMBER EXTRA | RATE | | |
|---|---|---|---|---|---|
| Total claims | 13 - 20 = | 0 | x $18.00 | **$0.00** | |
| Independent claims | 2 - 3 = | 0 | x $84.00 | **$0.00** | |
| Multiple Dependent Claims **(check if applicable).** | | | ☐ | **$0.00** | |
| **TOTAL OF ABOVE CALCULATIONS =** | | | | **$890.00** | |
| ☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2. | | | | **$0.00** | |
| **SUBTOTAL =** | | | | **$890.00** | |
| Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). + | | | | **$0.00** | |
| **TOTAL NATIONAL FEE =** | | | | **$890.00** | |
| Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** | | | ☒ | **$40.00** | |
| **TOTAL FEES ENCLOSED =** | | | | **$930.00** | |
| | | | | **Amount to be: refunded** | $ |
| | | | | **charged** | $ |

a. ☒ A check in the amount of **$930.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ______ in the amount of ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

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WE Vaughan

SIGNATURE

**William E. Vaughan**

NAME

**39,056**

REGISTRATION NUMBER

**October 22, 2001**

DATE

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

**PRELIMINARY AMENDMENT**

| | | | |
|---|---|---|---|
| APPLICANTS: | Gerhard Ritter | DOCKET NO.: | 0112740-339 |
| SERIAL NO: | Unknown | GROUP ART UNIT: | Unknown |
| FILED: | October 19, 2001 | EXAMINER: | Unknown |
| INTERNATIONAL APPLICATION NO:: | | PCT/DE00/01231 | |
| INTERNATIONAL FILING DATE | | April 19, 2000 | |
| INVENTION: | METHOD FOR CORRECTING FREQUENCY ERRORS IN SUBSCRIBER STATIONS | | |

Box PCT
Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

**In the Specification:**

Please replace the Specification of the present application, including the Abstract, with the following Substitute Specification:

SPECIFICATION

TITLE OF INVENTION

METHOD FOR CORRECTING
FREQUENCY ERRORS IN SUBSCRIBER STATIONS

BACKGROUND OF THE INVENTION

The present invention relates to a method for synchronizing the frequencies of subscriber stations of a radio communication system and to a subscriber station.

In radio communication systems, data (for example voice, video information or other data) are transmitted via a radio interface with the aid of electromagnetic waves. The radio interface relates to a connection between a base station and subscriber stations, where the subscriber stations can be mobile stations or stationary transceiver stations. The electromagnetic waves are radiated at carrier frequencies which are within the frequency band provided for the respective system. For future radio communication systems, for example the UMTS (Universal Mobile Telecommunication System) or other third-generation systems, frequencies within the frequency band of approx. 2000 MHz are provided.

In radio communication systems, only very small frequency deviations between base station and subscriber station are permissible in order to keep down the probability of detection errors. Whereas the base station can achieve very high frequency accuracy in a relatively simple manner, frequency deviations are unavoidable for the subscriber stations for reasons of costs, size and power consumption. It is intended to reduce these frequency deviations to a sufficiently small residual offset by synchronizing the frequencies of the subscriber stations to the base station.

In the GSM (Global System for Mobile Communication) mobile radio system, frequency correction by evaluating a separate radio burst of the base station for the determination of the frequency error by the mobile station is known. According to J. Eberspächer, H.-J.Vogel, "GSM Global System for Mobile Communication", Teubner Verlag, 1997, pages 83-84, this radio burst corresponds to an unmodulated carrier at fixed distance above the carrier frequency. This predetermines the measuring range and the measuring accuracy can only be increased by a correspondingly more elaborate evaluating circuit in the mobile stations.

## SUMMARY OF THE INVENTION

The present invention is directed toward a method for synchronizing the frequencies of subscriber stations which makes use of the resources of the radio interface and provides for accurate frequency synchronization.

In the method according to the present invention for synchronizing the frequencies of subscriber stations of a radio communication system, the subscriber station is connected to a base station via a radio interface. The subscriber station receives at least two separate measuring sequences of the base station and evaluates them with the subscriber station knowing the time interval between the two measuring sequences. A phase difference between the two measuring sequences is determined and a frequency deviation is determined from the phase difference. On the basis of the frequency deviation, a frequency standard can then be corrected.

Such measuring sequences may be short and may also be transmitted quite frequently, which does not tie up many radio engineering resources and there are many possibilities for forming the difference which leads to rapid and very accurate frequency synchronization.

According to embodiments of the present invention, the measuring sequences correspond to midambles within radio bursts or, respectively, pilot signals or parts thereof, the midambles or, respectively, pilot signals being provided for channel estimation. As an alternative, the measuring sequences are transmitted in addition to midambles or pilot signals. The two can also be combined with one another. Midambles or pilot signals are transmitted regularly for the channel estimation and their signal shape is known to the subscriber stations. Evaluation for the frequency synchronization does not mean any additional requirement for resources. Additional measuring sequences can supplement or replace the frequency synchronization via a greater number of measuring points even at the places at which normally no midambles or pilot signals are transmitted.

According to other embodiments of the present invention, the phase difference between successive measuring sequences or non-successive measuring sequences is determined. The greater the interval between the measuring sequences, the higher the measuring accuracy for the phase difference. The smaller the interval, the greater the measuring range.

It is, therefore, advantageous for the frequency synchronization of a subscriber station if first a measurement with a large measuring range and then, in another step, a

measurement with high measuring accuracy is performed. An iterative method will find the correct frequency unambiguously and with high accuracy. The frequency synchronization can be advantageously repeated cyclically during the operation of the subscriber station.

The arrangement of the measuring sequences in the signals of the base station can be adapted to the requirements for measuring range and accuracy. In other embodiments, the measuring sequences are arranged at the beginning and end of the radio burst for a bursty transmission, and the measuring sequences are arranged at the beginning and end of a section carrying data for a continuous transmission.

In the case of a mobile radio application, multipath propagation of the signals must be expected. Thus, influences of preceding signal components are still effective in the received signal in the subscriber station at the beginning of the reception of the measuring sequences and are superimposed on the measuring sequence. To increase the measuring accuracy, the beginning of the measuring sequences is not taken into consideration for determining the phase difference but only the parts of the measuring sequences arriving after an indirect path delay has elapsed.

According to another embodiment of the present invention, the phase differences determined are averaged before the frequency deviation is determined. During the determination of the average value and of the variance of the differences, a measure of the reliability of the measurement values is additionally obtained.

The method according to the present invention can be used in radio communication systems with CDMA (Code Division Multiple Access) subscriber separation both in FDD (Frequency Division Duplex) and in TDD (Time Division Duplex) mode. Another use is in a radio communication system with a radio interface according to a TDD transmission method with TD-CDMA (Time Division CDMA) subscriber separation and possibly directionally selective radiation pattern of the antennas. To make use of the flexible increase in capacity (soft capacity) by assigning additional codes or changing the spreading factor, the frequency bands have a wide bandwidth and the data components are spread with a subscriber- or channel-associated spreading code.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

## BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a block diagram of a mobile radio network.

Figure 2 shows a diagrammatic representation of the channel structure of the TDD and FDD transmission method.

Figure 3 shows a phase difference measurement via the downlink of the TDD transmission method.

Figure 4 shows measuring sequences in a bursty transmission.

Figure 5 shows measuring sequences in a continuous transmission.

Figure 6 shows a block diagram of a subscriber station.

## DETAILED DESCRIPTION OF THE INVENTION

The structure of the radio communication system shown in Figure 1 corresponds to a known GSM mobile radio network which consists of a multiplicity of mobile switching centers MSC which are networked together and establish access to a landline network PSTN. These mobile switching centers MSC are also connected to, in each case, at least one base station controller BSC. Each base station controller BSC in turn provides for a connection to at least one base station BS. Such a base station BS is a transceiver station which can set up a radio link to subscriber stations, e.g., mobile stations MS, via a radio interface.

Figure 1 shows an embodiment with three radio links for the transmission of user information and signaling information between three mobile stations MS and one base station BS, where two data channels DK1 and DK2 are allocated to one mobile station MS and in each case one data channel DK3 and DK4, respectively, are allocated to the other mobile stations MS. Each data channel DK1...DK4 represents one subscriber signal.

Control and maintenance functions for the mobile radio network or parts thereof are implemented by an operations and maintenance center OMC. The functions of this structure are used by the radio communication system according to the present invention; however, they can also be adopted in other radio communication systems in which the present invention can be used.

A transmission channel is characterized by a pseudorandom noise sequence, the spreading code. A particular spreading code is used for one transmission channel and is thus channel-oriented. A transmission channel is additionally marked by a carrier frequency and, in the case of the TDD mode, additionally by a timeslot. It is assumed that a first part of the mobile stations MS transmits voice information and a second part of the mobile stations MS transmits packet data.

Figure 2 shows the radio interface between the base station BS and mobile station MS in both transmission methods. The transmission in the different frequency bands FB1, FB2, FB3 is synchronized to one another. In this arrangement, broadband frequency bands with e.g., B = 1.6 or 5 MHz are used.

For both transmission embodiments and both directions of transmission, the signals of a number of subscriber stations MS are simultaneously transmitted in a frequency band FB1, FB2, FB3, a distinction being made via individual spreading codes. In consequence, a CDMA (Code Division Multiple Access) subscriber separation method is used which provides for simple adaptation of the data rate of a connection between the base station BS and subscriber station MS by allocating one or more spreading codes or changing the spreading factor.

In the TDD transmission embodiment, the switching point is followed by a time interval which is arbitrarily used by the subscriber stations MS as access channel for requesting a resource allocation. In the uplink UL, a bursty transmission in timeslots is used, a radio burst transmitted by a subscriber station MS in each case including one channel measuring sequence (midamble) ma in between two data components da. Between the radio bursts, transmission gaps are provided as guard bands for better separability of the received signals. In the downlink DL, the transmission is continuous.

In the FDD transmission embodiment, uplink UL and downlink DL are of the same type and are structured in accordance with the downlink DL of the TDD transmission method. During a continuous transmission, channel measuring sequences (pilot signals) ma and data components da cyclically alternate.

Another embodiment of the present invention can be used both in FDD mode and in TDD mode. The prerequisite for the frequency synchronization is the measurement of the phase difference of two measuring sequences, the time interval of which is known in the subscriber station MS. From $\Delta f = \Delta\varphi/\Delta t$, a frequency deviation can be determined which is used for correcting a frequency standard of the subscriber station MS.

For the measuring range and the measuring accuracy, however, the intervals dt (corresponding to $\Delta t$ in the above formula) between the measuring sequences must be noted. In the GSM mobile radio system, the interval of the midambles as channel measuring sequences is approx. 577 μs. The measuring range for the frequency deviation is thus approx. ±877 Hz. At a carrier frequency of approx. 900 MHz, this corresponds to a permissible frequency error of about $\pm 10^{-6}$. If the deviation is greater, ambiguities occur.

In other radio communication systems, the interval between the channel measuring sequences is usually between 400 and 700 μs (e.g., 625 μs in the case of UMTS). With 625 μs, a measuring range of approx. ±800 Hz is obtained. For a carrier frequency of approx. 2 GHz, a permissible frequency error of about $\pm 0.4 * 10^{-6}$ is obtained for an unambiguous measurement.

Due to the frequent emission of the channel measuring sequences, a great number of measurements per second are possible. This makes it possible to achieve a correspondingly high measuring accuracy. For a subscriber station MS, it is advantageous for initial synchronization in the sense of an iteration, first to evaluate successive measuring sequences in order to achieve a wide measuring range with unambiguous measurement, and then to evaluate non-successive measuring sequences in order to achieve a higher measuring accuracy within smaller measuring ranges. In

the case of a synchronization which is repeated cyclically later, it is possible to start immediately with a smaller measuring range.

To determine the phase difference from two measuring sequences, the measuring sequences have previously been equated to the channel measuring sequences (midambles or pilot signals). However, it is also possible to use separate phase measuring sequences by themselves or in combination with channel measuring sequences. Embodiments of these are shown in Figures 4 and 5.

This can be advantageous, for example, if a greater measuring range is used for the frequency deviation. For this purpose, measuring sequences for phase difference measurement are inserted in a channel. Figure 4 shows a radio burst which shows an embedded midamble ma in two data-carrying parts da. Additional measuring sequences are arranged at the beginning and at the end of the radio burst. The position and number of measuring sequences can also deviate from this in dependence on the requirements for measuring range and resolution.

According to Figure 3, only the inserted measuring sequences are used for measuring the phase difference. Another embodiment of the present invention provides that part-sequences of the channel measuring sequences are used for measuring the phase difference. It is also possible to measure the phase difference between channel measuring sequences and additional measuring sequences.

Figure 5 shows the insertion of the measuring sequences into signals of a continuous transmission. Between the channel measuring sequences ma, a data-carrying section da without transmission gap is arranged, the additional measuring sequences being arranged at the beginning and end of this data-carrying section da.

In a subscriber station MS according to Figure 6, received signals are received via an antenna and amplified in a receiving device, converted into the baseband and digitized. The digitized baseband signal with its quadature components is conducted, on the one hand directly and, on the other hand, delayed by the time interval dt of the measuring sequences, to a difference-forming circuit or differentiator D via a delay element DD.

In the differentiator D, the complex differences of the two signals are formed, the difference only being determined within the measuring sequences when the influence of the multipath propagation has decayed. This phase difference is post-processed in a control device SE and smoothed with the aid of a low-pass filter.

From the mean value for the phase difference, determined by the smoothing, a frequency deviation is determined via a table and a correcting voltage for a clock and frequency generator MC is determined in accordance with a tuning slope. This corrects the frequency standard of the clock and frequency generator MC. The correcting voltage of the clock and frequency generator MC corresponds to a closed-loop control device. Instead of the differentiator D in the form of a subtraction circuit D, an arrangement for the direct determination of the phase differences can also be used.

It should be understood that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. Such changes and modifications can be made without departing from the spirit and scope of the present invention and without diminishing its intended advantages. It is therefore intended that such changes and modifications be covered by the appended claims.

## ABSTRACT OF THE DISCLOSURE

A method for synchronizing the frequencies of subscriber stations of a radio communication system, wherein the subscriber station is connected to a base station via a radio interface, the subscriber station receives at least two separate measuring sequences of the base station and evaluates them, the time interval between the two measuring sequences being known to the subscriber station, a phase difference between the two measuring sequences is determined and a frequency deviation is determined from the phase difference, and thus, a frequency standard can be corrected on the basis of the frequency deviation.

**In the claims**:

On page 10, cancel line 1, and substitute the following left-hand justified heading therefor:

We Claim as Our Invention:

Please cancel claims 1-13, without prejudice, and substitute the following claims therefore:

14. A method for synchronizing the frequencies of subscriber stations of a radio communication system, in which a subscriber station is connected to a base station via a radio interface, the method comprising the steps of:

receiving at the subcriber station at least two separate measuring sequences of the base station;

evaluating the separate measuring sequences;

determining a phase difference between the two measuring sequences;

determining a frequency deviation from the phase difference; and

correcting a frequency standard on the basis of the frequency deviation.

15. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the measuring sequences correspond to midambles or parts of midambles within radio bursts, the midambles being provided for channel estimation.

16. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the measuring sequences are transmitted in addition to midambles.

17. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the phase difference is determined between successive measuring sequences.

18. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in any of claim 14, wherein the phase difference is determined between non-successive measuring sequences.

19. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the phase difference is first determined between successive measuring sequences, and is then determined between non-successive mearsing sequences.

20. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the measuring sequences are arranged at a beginning and an end of a radio burst for bursty transmission.

21. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the measuring sequences are arranged at a beginning and an end of a data-carrying section for continuous transmission.

22. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the beginning of the measuring sequences is not taken into consideration for determining the phase difference, but only parts of the measuring sequences arriving after an indirect path delay has elapsed.

23. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the phase differences determined are averaged before the frequency deviation is determined.

24. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the frequencies are synchronized in accordance with an iterative method.

25. A method for synchronizing the frequencies of subscriber stations of a radio communication system as claimed in claim 14, wherein the radio interface is organized in accordance with a TDD transmission method with TD-CDMA subscriber separation.

26. A subscriber station, comprising:

a receiving device for receiving signals of a base station via a radio interface;

a differentiator for evaluating two separate measuring sequences transmitted in the signals of the base station and for determining a phase difference between the two measuring sequences;

a control device for determining a frequency deviation from the phase difference, with knowledge of a time interval between the two measuring sequences; and

a closed-loop control device for correcting a frequency standard based on the frequency deviation.

## REMARKS

The present amendment makes editorial changes and corrects typographical errors in the specification, which includes the Abstract, in order to conform the specification to the requirements of United States Patent Practice. No new matter is added thereby. Attached hereto is a marked-up version of the changes made to the specification by the present amendment. The attached page is captioned "**Version With Markings To Show Changes Made**".

In addition, the present amendment cancels original claims 1-13 in favor of new claims 14-26. Claims 14-26 have been presented solely because the revisions by red-lining and underlining which would have been necessary in claims 1-13 in order to present those claims in accordance with preferred United States Patent Practice would

have been too extensive, and thus would have been too burdensome. The present amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 USC §§103, 102, 103 or 112. Indeed, the cancellation of claims 1-13 does not constitute an intent on the part of the Applicants to surrender any of the subject matter of claims 1-13.

Early consideration on the merits is respectfully requested.

Respectfully submitted,

(Reg. No. 39,056)

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Attorneys for Applicant

## VERSIONS WITH MARKINGS TO SHOW CHANGES MADE

**In The Specification:**

The Specification of the present application, including the Abstract, has been amended as follows:

SPECIFICATION

TITLE OF INVENTION

METHOD FOR CORRECTING
FREQUENCY ERRORS IN SUBSCRIBER STATIONS

BACKGROUND OF THE INVENTION

The present invention relates to a method for synchronizing the frequencies of subscriber stations of a radio communication system and to a subscriber station ~~constructed in this manner~~.

In radio communication systems, data (for example voice, video information or other data) are transmitted via a radio interface with the aid of electromagnetic waves. The radio interface relates to a connection between a base station and subscriber stations, where the subscriber stations can be mobile stations or stationary transceiver stations. The electromagnetic waves are radiated at carrier frequencies which are within the frequency band provided for the respective system. For future radio communication systems, for example the UMTS (Universal Mobile Telecommunication System) or other third-generation systems, frequencies within the frequency band of approx. 2000 MHz are provided.

In radio communication systems, only very small frequency deviations between base station and subscriber station are permissible in order to keep down the probability of detection errors. Whereas the base station can achieve very high frequency accuracy in a relatively simple manner, frequency deviations are unavoidable for the subscriber stations for reasons of costs, size and power consumption. It is intended to reduce these frequency deviations to a sufficiently small residual offset by synchronizing the frequencies of the subscriber stations to the base station.

In the GSM (Global System for Mobile Communication) mobile radio system, frequency correction by evaluating a separate radio burst of the base station for the determination of the frequency error by the mobile station is known. According to J. Eberspächer, H.-J.Vogel, "GSM Global System for Mobile Communication", Teubner Verlag, 1997, pages 83-84, this radio burst corresponds to an unmodulated carrier at fixed distance above the carrier frequency. This predetermines the measuring range and the measuring accuracy can only be increased by a correspondingly more elaborate evaluating circuit in the mobile stations.

## SUMMARY OF THE INVENTION

The present invention is directed toward ~~The invention is based on the object of specifying~~ a method for synchronizing the frequencies of subscriber stations which makes ~~good~~ use of the resources of the radio interface and provides for accurate frequency synchronization. ~~This object is achieved by the method having the features of claim 1 and the subscriber station having the features of claim 13. Advantageous further developments of the invention can be found in the subclaims.~~

In the method according to the present invention for synchronizing the frequencies of subscriber stations of a radio communication system, the subscriber station is connected to a base station via a radio interface. The subscriber station receives at least two separate measuring sequences of the base station and evaluates them~~,~~ with the subscriber station knowing the time interval between the two measuring sequences. A phase difference between the two measuring sequences is determined and a frequency deviation is determined from the phase difference. On the basis of the frequency deviation, a frequency standard can then be corrected.

Such measuring sequences ~~can~~ may be short and ~~can~~ may also be transmitted quite frequently, which does not tie up many radio engineering resources and there are many possibilities for forming the difference which ~~lead~~ leads to rapid and very accurate frequency synchronization.

According to ~~advantageous~~ embodiments of the present invention, the measuring sequences correspond to midambles within radio bursts or, respectively, pilot signals or parts thereof, the midambles or, respectively, pilot signals being

provided for channel estimation. As an alternative, the measuring sequences are transmitted in addition to midambles or pilot signals. The two can also be combined with one another. Midambles or pilot signals are transmitted regularly for the channel estimation and their signal shape is known to the subscriber stations. Evaluation for the frequency synchronization does not mean any additional requirement for resources. Additional measuring sequences can supplement or replace the frequency synchronization ~~by means of~~ via a greater number of measuring points even at the places at which normally no midambles or pilot signals are transmitted.

According to ~~further advantageous~~ other embodiments of the present invention, the phase difference between successive measuring sequences or non-successive measuring sequences is determined. The greater the interval between the measuring sequences, the higher the measuring accuracy for the phase difference. The smaller the interval, the greater the measuring range.

It is, therefore, ~~of advantage~~ advantageous for the frequency synchronization of a subscriber station if first a measurement with a large measuring range and then, in ~~a further~~ another step, a measurement with high measuring accuracy is performed. An iterative method will find the correct frequency unambiguously and with high accuracy. The frequency synchronization can be advantageously repeated cyclically during the operation of the subscriber station.

The arrangement of the measuring sequences in the signals of the base station can be adapted to the requirements for measuring range and accuracy. In other embodiments, ~~Advantageous possibilities are:~~ the measuring sequences are arranged at the beginning and end of the radio burst for a bursty transmission, and the measuring sequences are arranged at the beginning and end of a section carrying data for a continuous transmission.

In the case of a mobile radio application, multipath propagation of the signals must be expected. Thus, influences of preceding signal components are still effective in the received signal in the subscriber station at the beginning of the reception of the measuring sequences and are superimposed on the measuring sequence. To increase the measuring accuracy, ~~it is advantageous that~~ the beginning of the measuring

sequences is not taken into consideration for determining the phase difference but only the parts of the measuring sequences arriving after an indirect path delay has elapsed.

According to ~~a further~~ another embodiment of the present invention, the phase differences determined are averaged before the frequency deviation is determined. During the determination of the average value and of the variance of the differences, a measure of the reliability of the measurement values is additionally obtained.

The method according to the present invention can be ~~advantageously~~ used in radio communication systems with CDMA (Code Division Multiple Access) subscriber separation both in FDD (Frequency Division Duplex) and in TDD (Time Division Duplex) mode. ~~Use~~ Another use is in a radio communication system with a radio interface according to a TDD transmission method with TD-CDMA (Time Division CDMA) subscriber separation and possibly directionally selective radiation pattern of the antennas ~~is particularly advantageous~~. To make use ~~of the advantages~~ of the flexible increase in capacity (soft capacity) by assigning additional codes or changing the spreading factor, the frequency bands have a wide bandwidth and the data components are spread with a subscriber- or channel-associated spreading code.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

~~Exemplary embodiments of the invention will be explained in greater detail with reference to the attached drawings, in which:~~

## BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a block diagram of a mobile radio network~~,~~.

Figure 2 shows a diagrammatic representation of the channel structure of the TDD and FDD transmission method~~,~~.

Figure 3 shows a phase difference measurement ~~by means of~~ via the downlink of the TDD transmission method~~,~~.

Figure 4 shows measuring sequences in a bursty transmission~~,~~.

Figure 5 shows measuring sequences in a continuous transmission ~~and~~.

Figure 6 shows a block diagram of a subscriber station.

## DETAILED DESCRIPTION OF THE INVENTION

The structure of the radio communication system shown in Figure 1 corresponds to a known GSM mobile radio network which consists of a multiplicity of mobile switching centers MSC which are networked together and establish access to a landline network PSTN. These mobile switching centers MSC are also connected to, in each case, at least one base station controller BSC. Each base station controller BSC in turn provides for a connection to at least one base station BS. Such a base station BS is a transceiver station which can set up a radio link to subscriber stations, e.g., mobile stations MS, via a radio interface.

Figure 1 shows ~~as an example~~ an embodiment with three radio links for the transmission of user information and signaling information between three mobile stations MS and one base station BS, where two data channels DK1 and DK2 are allocated to one mobile station MS and in each case one data channel DK3 and DK4, respectively, are allocated to the other mobile stations MS. Each data channel DK1...DK4 represents one subscriber signal.

Control and maintenance functions for the mobile radio network or parts thereof are implemented by an operations and maintenance center OMC. The functions of this structure are used by the radio communication system according to the present invention; however, they can also be adopted in other radio communication systems in which the present invention can be used.

A transmission channel is characterized by a pseudorandom noise sequence, the spreading code. A particular spreading code is used for one transmission channel and is thus channel-oriented. A transmission channel is additionally marked by a carrier frequency and, in the case of the TDD mode, additionally by a timeslot. It is assumed that a first part of the mobile stations MS transmits voice information and a second part of the mobile stations MS transmits packet data.

Figure 2 shows the radio interface between the base station BS and mobile station MS in both transmission methods. The transmission in the different frequency

bands FB1, FB2, FB3 is synchronized to one another. In this arrangement, broadband frequency bands with e.g., B = 1.6 or 5 MHz are used.

For both transmission ~~methods~~ embodiments and both directions of transmission, the signals of a number of subscriber stations MS are simultaneously transmitted in a frequency band FB1, FB2, FB3, a distinction being made ~~by means of~~ via individual spreading codes. In consequence, a CDMA (Code Division Multiple Access) subscriber separation method is used which provides for simple adaptation of the data rate of a connection between the base station BS and subscriber station MS by allocating one or more spreading codes or changing the spreading factor.

In the TDD transmission ~~method~~ embodiment, the switching point is followed by a time interval which is arbitrarily used by the subscriber stations MS as access channel for requesting a resource allocation. In the uplink UL, a bursty transmission in timeslots is used, a radio burst transmitted by a subscriber station MS in each case ~~comprising~~ including one channel measuring sequence (midamble) ma in between two data components da. Between the radio bursts, transmission gaps are provided as guard bands for better separability of the received signals. In the downlink DL, the transmission is continuous.

In the FDD transmission ~~method,~~ embodiment, uplink UL and downlink ~~UL,~~ DL are of the same type and are structured in accordance with the downlink DL of the TDD transmission method. During a continuous transmission, channel measuring sequences (pilot signals) ma and data components da cyclically alternate.

~~The method according to the~~ Another embodiment of the present invention can be used both in FDD mode and in TDD mode. The prerequisite for the frequency synchronization is the measurement of the phase difference of two measuring sequences, the time interval of which is known in the subscriber station MS. From $\Delta f = \Delta\varphi / \Delta t$, a frequency deviation can be determined which is used for correcting a frequency standard of the subscriber station MS.

For the measuring range and the measuring accuracy, however, the intervals dt (corresponding to $\Delta t$ in the above formula) between the measuring sequences must be noted. In the GSM mobile radio system, the interval of the midambles as channel

measuring sequences is approx. 577 µs. The measuring range for the frequency deviation is thus approx. ±877 Hz. At a carrier frequency of approx. 900 MHz, this corresponds to a permissible frequency error of about $\pm 10^{-6}$. If the deviation is greater, ambiguities occur.

In other radio communication systems, ~~too,~~ the interval between the channel measuring sequences is usually between 400 and 700 µs (e.g., 625 µs in the case of UMTS). With 625 µs, a measuring range of approx. ±800 Hz is obtained. For a carrier frequency of approx. 2 GHz, a permissible frequency error of about $\pm 0.4 * 10^{-6}$ is obtained for an unambiguous measurement.

Due to the frequent emission of the channel measuring sequences, a great number of measurements per second are possible. This makes it possible to achieve a correspondingly high measuring accuracy. For a subscriber station MS, it is ~~of advantage~~ advantageous for initial synchronization in the sense of an iteration, first to evaluate successive measuring sequences in order to achieve a wide measuring range with unambiguous measurement, and then to evaluate non-successive measuring sequences in order to achieve a higher measuring accuracy within smaller measuring ranges. In the case of a synchronization which is repeated cyclically later, it is possible to start immediately with a smaller measuring range.

To determine the phase difference from two measuring sequences, the measuring sequences have previously been equated to the channel measuring sequences (midambles or pilot signals). However, it is also possible to use separate phase measuring sequences by themselves or in combination with channel measuring sequences. ~~Examples~~ Embodiments of these are shown in Figures 4 and 5.

This can be advantageous, for example, if a greater measuring range is used for the frequency deviation. For this purpose, measuring sequences for phase difference measurement are inserted in a channel. Figure 4 shows a radio burst which shows an embedded midamble ma in two data-carrying parts da. Additional measuring sequences are arranged at the beginning and at the end of the radio burst. The position and number of measuring sequences can also deviate from this in dependence on the requirements for measuring range and resolution.

According to Figure 3, only the inserted measuring sequences are used for measuring the phase difference. ~~A further~~ Another embodiment of the present invention provides that part-sequences of the channel measuring sequences are used for measuring the phase difference. It is also possible to measure the phase difference between channel measuring sequences and additional measuring sequences.

Figure 5 shows the insertion of the measuring sequences into signals of a continuous transmission. Between the channel measuring sequences ma, a data-carrying section da without transmission gap is arranged, the additional measuring sequences being arranged at the beginning and end of this data-carrying section da.

In a subscriber station MS according to Figure 6, received signals are received via an antenna and amplified in a receiving device, converted into the baseband and digitized. The digitized baseband signal with its quadature components is conducted, on the one hand directly and, on the other hand, delayed by the time interval dt of the measuring sequences, to a difference-forming circuit or differentiator D via a delay element DD.

In the differentiator D, the complex differences of the two signals are formed, the difference only being determined within the measuring sequences when the influence of the multipath propagation has decayed. This phase difference is post-processed in a control device SE and smoothed with the aid of a low-pass filter.

From the mean value for the phase difference, determined by the smoothing, a frequency deviation is determined via a table and a correcting voltage for a clock and frequency generator MC is determined in accordance with a tuning slope. This corrects the frequency standard of the clock and frequency generator MC. The ~~[lacuna]~~ correcting voltage of the clock and frequency generator MC corresponds to a closed-loop control device. Instead of the differentiator D in the form of a subtraction circuit D, an arrangement for the direct determination of the phase differences can also be used.

~~Abstract~~ It should be understood that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. Such changes and modifications can be made without departing from the spirit

and scope of the present invention and without diminishing its intended advantages. It is therefore intended that such changes and modifications be covered by the appended claims.

~~Correction of frequency errors in subscriber stations~~

## ABSTRACT OF THE DISCLOSURE

~~In the method according to the invention~~ A method for synchronizing the frequencies of subscriber stations of a radio communication system, wherein the subscriber station is connected to a base station via a radio interface~~. The~~, the subscriber station receives at least two separate measuring sequences of the base station and evaluates them, the time interval between the two measuring sequences being known to the subscriber station~~. A~~, a phase difference between the two measuring sequences is determined and a frequency deviation is determined from the phase difference~~. Thus,~~, and thus, a frequency standard can be corrected on the basis of the frequency deviation.

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531 Rec'd PCT/... 22 OCT 2001

Description

Correction of frequency errors in subscriber stations

The invention relates to a method for synchronizing the frequencies of subscriber stations of a radio communication system and to a subscriber station constructed in this manner.

In radio communication systems, data (for example voice, video information or other data) are transmitted via a radio interface with the aid of electromagnetic waves. The radio interface relates to a connection between a base station and subscriber stations, where the subscriber stations can be mobile stations or stationary transceiver stations. The electromagnetic waves are radiated at carrier frequencies which are within the frequency band provided for the respective system. For future radio communication systems, for example the UMTS (Universal Mobile Telecommunication System) or other third-generation systems, frequencies within the frequency band of approx. 2000 MHz are provided.

In radio communication systems, only very small frequency deviations between base station and subscriber station are permissible in order to keep down the probability of detection errors. Whereas the base station can achieve very high frequency accuracy in a relatively simple manner, frequency deviations are unavoidable for the subscriber stations for reasons of costs, size and power consumption. It is intended to reduce these frequency deviations to a sufficiently small residual offset by synchronizing the frequencies of the subscriber stations to the base station.

In the GSM (Global System for Mobile Communication) mobile radio system, frequency correction by evaluating a separate radio burst of the base station for the

determination of the frequency error by the mobile station is known. According to J.

Eberspächer, H.-J.Vogel, "GSM Global System for Mobile Communication", Teubner Verlag, 1997, pages 83-84, this radio burst corresponds to an unmodulated carrier at fixed distance above the carrier frequency. This predetermines the measuring range and the measuring accuracy can only be increased by a correspondingly more elaborate evaluating circuit in the mobile stations.

The invention is based on the object of specifying a method for synchronizing the frequencies of subscriber stations which makes good use of the resources of the radio interface and provides for accurate frequency synchronization. This object is achieved by the method having the features of claim 1 and the subscriber station having the features of claim 13. Advantageous further developments of the invention can be found in the subclaims.

In the method according to the invention for synchronizing the frequencies of subscriber stations of a radio communication system, the subscriber station is connected to a base station via a radio interface. The subscriber station receives at least two separate measuring sequences of the base station and evaluates them, the subscriber station knowing the time interval between the two measuring sequences. A phase difference between the two measuring sequences is determined and a frequency deviation is determined from the phase difference. On the basis of the frequency deviation, a frequency standard can then be corrected.

Such measuring sequences can be short and can also be transmitted quite frequently, which does not tie up many radio engineering resources and there are many possibilities for forming the difference which lead to rapid and very accurate frequency synchronization.

According to advantageous embodiments of the invention, the measuring sequences correspond to midambles within radio bursts or, respectively, pilot signals or parts thereof, the midambles or, respectively, pilot signals being provided for channel estimation. As an alternative, the measuring sequences are transmitted in addition to midambles or pilot signals. The two can also be combined with one another. Midambles or pilot signals are transmitted regularly for the channel estimation and their signal shape is known to the subscriber stations. Evaluation for the frequency synchronization does not mean any additional requirement for resources. Additional measuring sequences can supplement or replace the frequency synchronization by means of a greater number of measuring points even at the places at which normally no midambles or pilot signals are transmitted.

According to further advantageous embodiments of the invention, the phase difference between successive measuring sequences or non-successive measuring sequences is determined. The greater the interval between the measuring sequences, the higher the measuring accuracy for the phase difference. The smaller the interval, the greater the measuring range.

It is, therefore, of advantage for the frequency synchronization of a subscriber station if first a measurement with a large measuring range and then, in a further step, a measurement with high measuring accuracy is performed. An iterative method will find the correct frequency unambiguously and with high accuracy. The frequency synchronization can be advantageously repeated cyclically during the operation of the subscriber station.

The arrangement of the measuring sequences in the signals of the base station can be adapted to the

requirements for measuring range and accuracy. Advantageous possibilities are:
the measuring sequences are arranged at the beginning and end of the radio burst for a bursty transmission,
the measuring sequences are arranged at the beginning and end of a section carrying data for a continuous transmission.
In the case of a mobile radio application, multipath propagation of the signals must be expected. Thus, influences of preceding signal components are still effective in the received signal in the subscriber station at the beginning of the reception of the measuring sequences and are superimposed on the measuring sequence. To increase the measuring accuracy, it is advantageous that the beginning of the measuring sequences is not taken into consideration for determining the phase difference but only the parts of the measuring sequences arriving after an indirect path delay has elapsed.

According to a further embodiment of the invention, the phase differences determined are averaged before the frequency deviation is determined. During the determination of the average value and of the variance of the differences, a measure of the reliability of the measurement values is additionally obtained.

The method according to the invention can be advantageously used in radio communication systems with CDMA (Code Division Multiple Access) subscriber separation both in FDD (Frequency Division Duplex) and in TDD (Time Division Duplex) mode. Use in a radio communication system with a radio interface according to a TDD transmission method with TD-CDMA (Time Division CDMA) subscriber separation and possibly directionally selective radiation pattern of the antennas is particularly advantageous. To make use of the advantages of the flexible increase in capacity (soft capacity) by assigning additional codes or

changing the spreading factor, the frequency bands have a wide bandwidth and the data components are spread with a subscriber- or channel-associated spreading code.

Exemplary embodiments of the invention will be explained in greater detail with reference to the attached drawings, in which:

Figure 1 shows a block diagram of a mobile radio network,

Figure 2 shows a diagrammatic representation of the channel structure of the TDD and FDD transmission method,

Figure 3 shows a phase difference measurement by means of the downlink of the TDD transmission method,

Figure 4 shows measuring sequences in a bursty transmission,

Figure 5 shows measuring sequences in a continuous transmission and

Figure 6 shows a block diagram of a subscriber station.

The structure of the radio communication system shown in Figure 1 corresponds to a known GSM mobile radio network which consists of a multiplicity of mobile switching centers MSC which are networked together and establish access to a landline network PSTN. These mobile switching centers MSC are also connected to in each case at least one base station controller BSC. Each base station controller BSC in turn provides for a connection to at least one base station BS. Such a base station BS is a transceiver station which can set up a radio link to subscriber stations, e.g. mobile stations MS, via a radio interface.

Figure 1 shows as an example three radio links for the transmission of user information and signaling information between three mobile stations MS and one base station BS, where two data channels DK1 and DK2 are allocated to one mobile station MS and in each case one data channel DK3 and DK4, respectively, are allocated to the other mobile stations MS. Each data channel DK1…DK4 represents one subscriber signal.

Control and maintenance functions for the mobile radio network or parts thereof are implemented by an operations and maintenance center OMC. The functions of this structure are used by the radio communication system according to the invention; however, they can also be adopted in other radio communication systems in which the invention can be used.
A transmission channel is characterized by a pseudorandom noise sequence, the spreading code. A particular spreading code is used for one transmission channel and is thus channel-oriented. A transmission channel is additionally marked by a carrier frequency and, in the case of the TDD mode, additionally by a timeslot. It is assumed that a first part of the mobile stations MS transmits voice information and a second part of the mobile stations MS transmits packet data.

Figure 2 shows the radio interface between the base station BS and mobile station MS in both transmission methods. The transmission in the different frequency bands FB1, FB2, FB3 is synchronized to one another. In this arrangement, broadband frequency bands with e.g. B = 1.6 or 5 MHz are used.

For both transmission methods and both directions of transmission, the signals of a number of subscriber stations MS are simultaneously transmitted in a frequency band FB1, FB2, FB3, a distinction being made by means of individual spreading codes. In consequence, a CDMA (Code Division Multiple Access) subscriber separation method is used which provides for simple adaptation of the data rate of a connection between the base station BS and subscriber station MS by allocating one or more spreading codes or changing the spreading factor.

In the TDD transmission method, the switching point is followed by a time interval which is arbitrarily used by the subscriber stations MS as access channel for

requesting a resource allocation. In the uplink UL, a bursty transmission in timeslots is used, a radio burst transmitted by a subscriber station MS in each case comprising one channel measuring sequence (midamble) ma in between two data components da. Between the radio bursts, transmission gaps are provided as guard bands for better separability of the received signals. In the downlink DL, the transmission is continuous.
In the FDD transmission method, uplink and downlink UL, DL are of the same type and are structured in accordance with the downlink DL of the TDD transmission method. During a continuous transmission, channel measuring sequences (pilot signals) ma and data components da cyclically alternate.

The method according to the invention can be used both in FDD mode and in TDD mode. The prerequisite for the frequency synchronization is the measurement of the phase difference of two measuring sequences, the time interval of which is known in the subscriber station MS. From $\Delta f = \Delta\varphi / \Delta t$, a frequency deviation can be determined which is used for correcting a frequency standard of the subscriber station MS.

For the measuring range and the measuring accuracy, however, the intervals dt (corresponding to $\Delta t$ in the above formula) between the measuring sequences must be noted. In the GSM mobile radio system, the interval of the midambles as channel measuring sequences is approx. 577 µs. The measuring range for the frequency deviation is thus approx. ±877 Hz. At a carrier frequency of approx. 900 MHz, this corresponds to a permissible frequency error of about $\pm 10^{-6}$. If the deviation is greater, ambiguities occur.

In other radio communication systems, too, the interval between the channel measuring sequences is usually between 400 and 700 µs (e.g. 625 µs in the case of UMTS). With 625 µs, a measuring range of

approx. ±800 Hz is obtained. For a carrier frequency of approx. 2 GHz, a permissible frequency error of about $\pm 0.4*10^{-6}$ is obtained for an unambiguous measurement.

Due to the frequent emission of the channel measuring sequences, a great number of measurements per second are possible. This makes it possible to achieve a correspondingly high measuring accuracy. For a subscriber station MS, it is of advantage for initial synchronization in the sense of an iteration, first to evaluate successive measuring sequences in order to achieve a wide measuring range with

unambiguous measurement, and then to evaluate non-successive measuring sequences in order to achieve a higher measuring accuracy within smaller measuring ranges. In the case of a synchronization which is repeated cyclically later, it is possible to start immediately with a smaller measuring range.

To determine the phase difference from two measuring sequences, the measuring sequences have previously been equated to the channel measuring sequences (midambles or pilot signals). However, it is also possible to use separate phase measuring sequences by themselves or in combination with channel measuring sequences. Examples of these are shown in Figures 4 and 5.

This can be advantageous, for example, if a greater measuring range is used for the frequency deviation. For this purpose, measuring sequences for phase difference measurement are inserted in a channel. Figure 4 shows a radio burst which shows an embedded midamble ma in two data-carrying parts da. Additional measuring sequences are arranged at the beginning and at the end of the radio burst. The position and number of measuring sequences can also deviate from this in dependence on the requirements for measuring range and resolution.

According to Figure 3, only the inserted measuring sequences are used for measuring the phase difference. A further embodiment provides that part-sequences of the channel measuring sequences are used for measuring the phase difference. It is also possible to measure the phase difference between channel measuring sequences and additional measuring sequences.

Figure 5 shows the insertion of the measuring sequences into signals of a continuous transmission. Between the channel measuring sequences ma, a data-carrying section da without transmission gap is arranged, the additional

measuring sequences being arranged at the beginning and end of this data-carrying section da.

In a subscriber station MS according to Figure 6, received signals are received via an antenna and amplified in a receiving device, converted into the baseband and digitized. The digitized baseband signal with its quadature components is conducted, on the one hand directly and, on the other hand, delayed by the time interval dt of the measuring sequences, to a difference-forming circuit or differentiator D via a delay element DD.

In the differentiator D, the complex differences of the two signals are formed, the difference only being determined within the measuring sequences when the influence of the multipath propagation has decayed. This phase difference is post-processed in a control device SE and smoothed with the aid of a low-pass filter.

From the mean value for the phase difference, determined by the smoothing, a frequency deviation is determined via a table and a correcting voltage for a clock and frequency generator MC is determined in accordance with a tuning slope. This corrects the frequency standard of the clock and frequency generator MC. The [lacuna] of the clock and frequency generator MC corresponds to a closed-loop control device. Instead of the differentiator D in the form of a subtraction circuit D, an arrangement for the direct determination of the phase differences can also be used.

Patent Claims

1. A method for synchronizing the frequencies of subscriber stations (MS) of a radio communication system, in which a subscriber station (MS)
   - is connected to a base station (BS) via a radio interface,
   - receives and evaluates at least two separate measuring sequences of the base station (BS), the time interval between the two measuring sequences being known to the subscriber station (MS),
   - determines a phase difference between the two measuring sequences,
   - determines a frequency deviation from the phase difference,
   - corrects a frequency standard on the basis of the frequency deviation.

2. The method as claimed in claim 1, in which the measuring sequences correspond to midambles or parts of midambles within radio bursts, the midambles being provided for channel estimation.

3. The method as claimed in one of the preceding claims, in which the measuring sequences are transmitted in addition to midambles.

4. The method as claimed in one of the preceding claims, in which the phase difference is determined between successive measuring sequences.

5. The method as claimed in one of claims 1 to 3, in which the phase difference is determined between non-successive measuring sequences.

6. The method as claimed in claims 4 and 5, in which first the method according to claim 4 and then the method according to claim 5 are performed for a synchronization of frequencies.

7. The method as claimed in one of the preceding claims, in which the measuring sequences are arranged at the beginning and end of the radio burst for bursty transmission.

8. The method as claimed in one of claims 1 to 6, in which the measuring sequences are arranged at the beginning and end of a data-carrying section for continuous transmission.

9. The method as claimed in one of the preceding claims, in which the beginning of the measuring sequences is not taken into consideration for determining the phase difference, but only the parts of the measuring sequences arriving after an indirect path delay has elapsed.

10. The method as claimed in one of the preceding claims, in which the phase differences determined are averaged before the frequency deviation is determined.

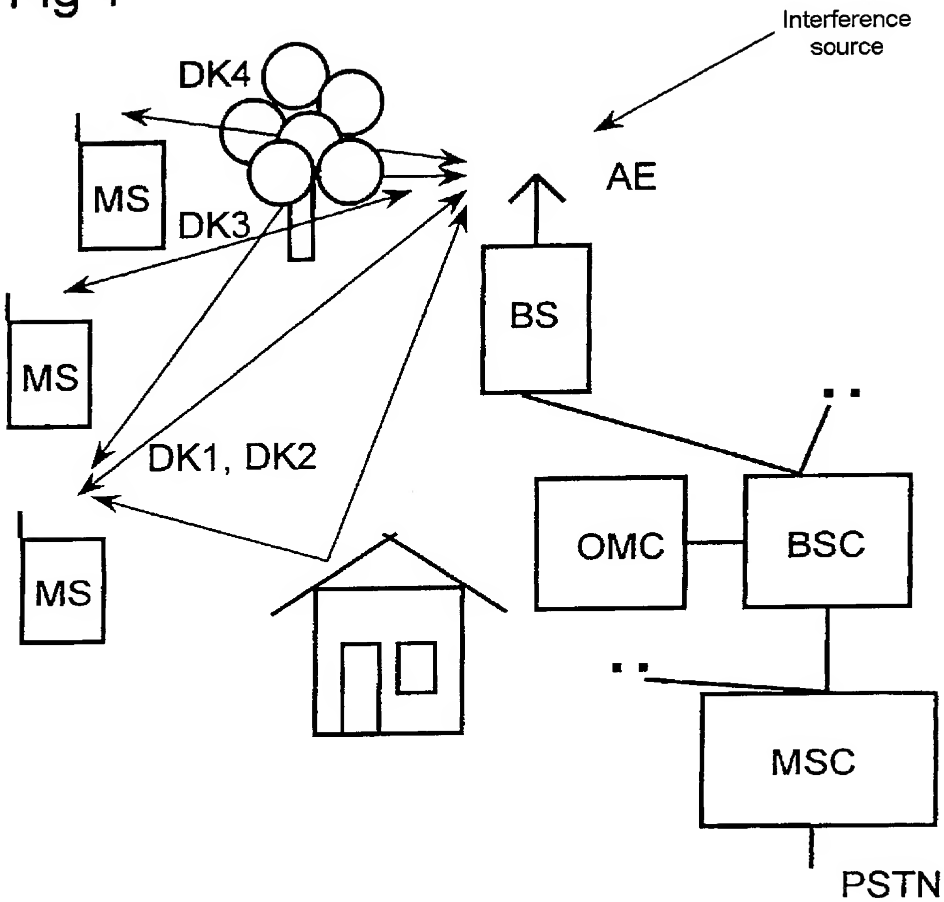
11. The method as claimed in one of the preceding claims, in which the frequencies are synchronized in accordance with an iterative method.

12. The method as claimed in one of the preceding claims, in which the radio interface is organized in accordance with a TDD transmission method with TD-CDMA subscriber separation.

13. A subscriber station (MS)
with a receiving device (EE) for receiving signals of a base station (BS) via a radio interface,
with a differentiator (D) for evaluating two separate measuring sequences transmitted in the signals of the base station (BS) and for determining a phase difference between the two measuring sequences,

with a control device (SE) for determining a frequency deviation from the phase difference, with knowledge of the time interval between the two measuring sequences, and, with a closed-loop control device for correcting a frequency standard on the basis of the frequency deviation.

Fig 1



Interference source
DK4
MS
DK3
AE
BS
MS
DK1, DK2
MS
OMC
BSC
MSC
PSTN

Fig 2

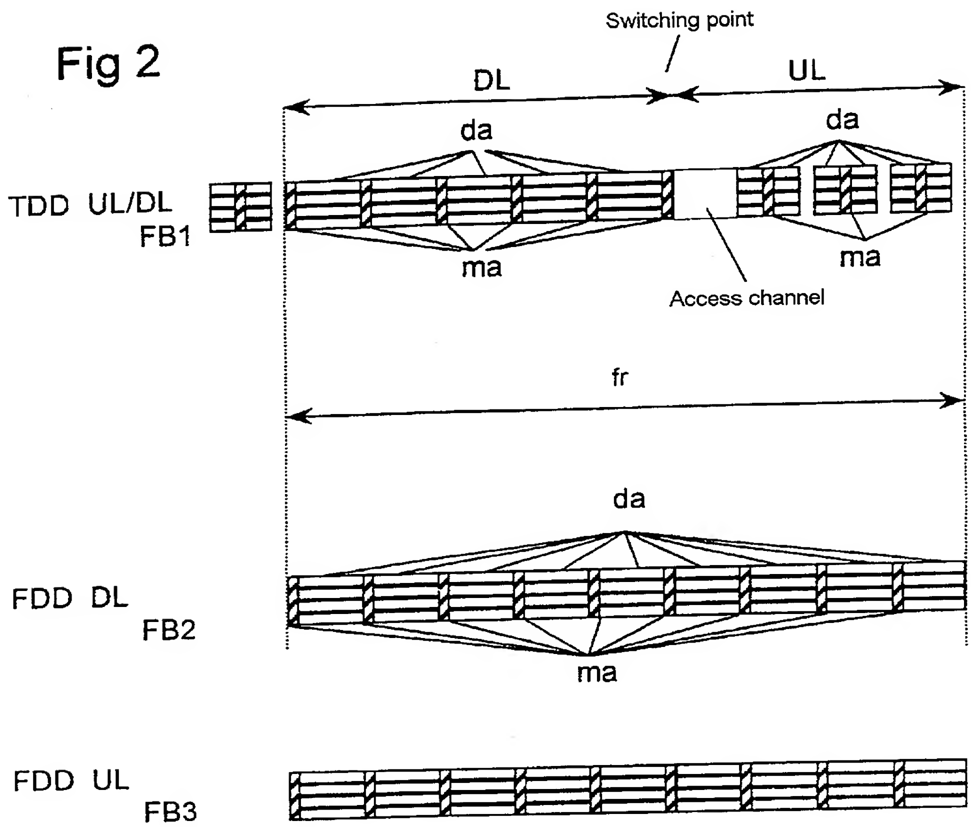

Switching point
DL
UL
da
da
TDD UL/DL
FB1
ma
ma
Access channel
fr
da
FDD DL
FB2
ma
FDD UL
FB3

Fig 3

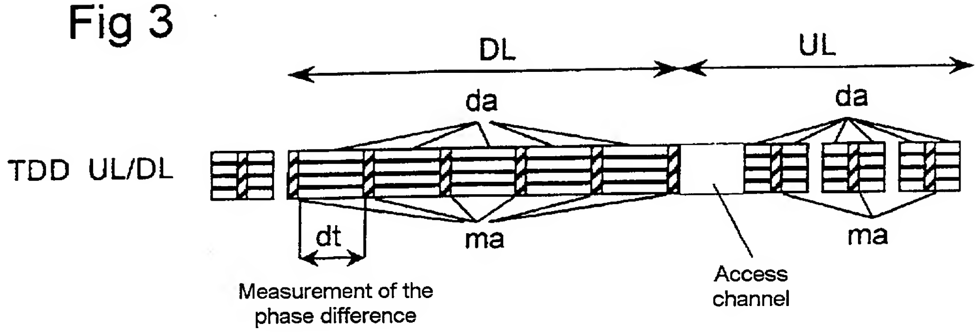



Fig 4

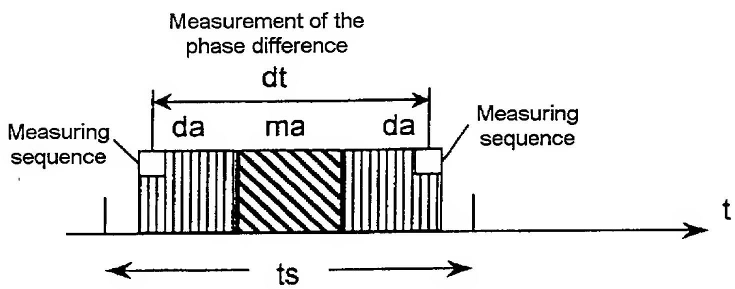



Fig 5

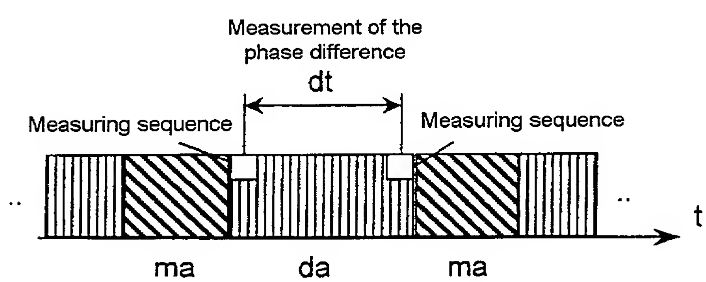
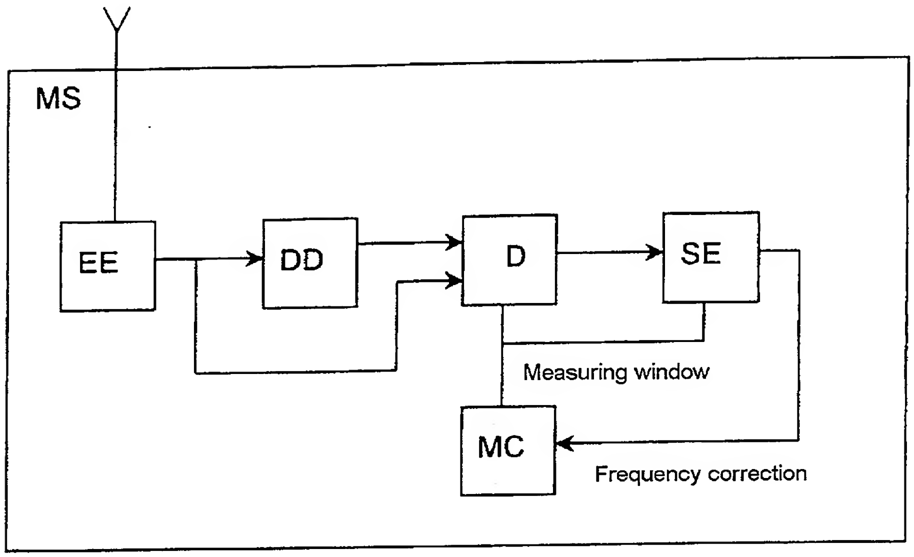


Fig 6



# Declarat[illegible]n and Power of Attorney F[illegible] Patent Application
## *Erklärung Für Patentanmeldungen Mit Vollmacht*
### German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Korrektur von Frequenzfehlern in Teilnehmerstationen

Correction of frequency errors in subscriber stations

deren Beschreibung

(zutreffendes ankreuzen)

☐ hier beigefügt ist.

☒ am 19.04.2000 als PCT internationale Anmeldung

PCT Anmeldungsnummer PCT/DE00/01231

eingereicht wurde und am ________ abgeändert wurde (falls tatsächlich abgeändert).

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on 19.04.2000 as PCT international application

PCT Application No. PCT/DE00/01231

and was amended on ________ (if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

## German Language Declaration

Prior foreign appplications
Priorität beansprucht

**Priority Claimed**

| | | | | |
|---|---|---|---|---|
| 19918373.2 | DE | 22.04.1999 | ☒ | ☐ |
| (Number) | (Country) | (Day Month Year Filed) | Yes | No |
| (Nummer) | (Land) | (Tag Monat Jahr eingereicht) | Ja | Nein |
| | | | ☐ | ☐ |
| (Number) | (Country) | (Day Month Year Filed) | Yes | No |
| (Nummer) | (Land) | (Tag Monat Jahr eingereicht) | Ja | Nein |
| | | | ☐ | ☐ |
| (Number) | (Country) | (Day Month Year Filed) | Yes | No |
| (Nummer) | (Land) | (Tag Monat Jahr eingereicht) | Ja | Nein |

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

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|---|---|---|---|
| PCT/DE00/01231 | 19.04.2000 | anhängig | pending |
| (Application Serial No.)<br>(Anmeldeseriennummer) | (Filing Date D, M, Y)<br>(Anmeldedatum T, M, J) | (Status)<br>(patentiert, anhängig, aufgegeben) | (Status)<br>(patented, pending, abandoned) |
| | | | |
| (Application Serial No.)<br>(Anmeldeseriennummer) | (Filing Date D,M,Y)<br>(Anmeldedatum T, M; J) | (Status)<br>(patentiert, anhängig, aufgeben) | (Status)<br>(patented, pending, abandoned) |

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

## German Language Declaration

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

And I hereby appoint

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*(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).*

*(Supply similar information and signature for third and subsequent joint inventors).*